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W. H. T. HOLDEN

2,155,230

PEAK VOLTAGE LIMITER

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FIG. 1

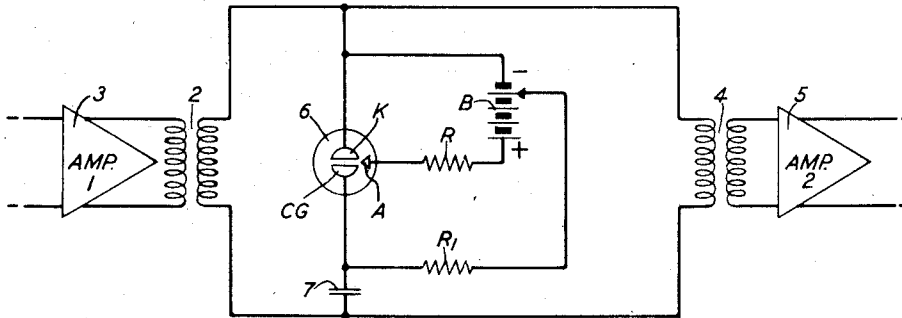


FIG. 2

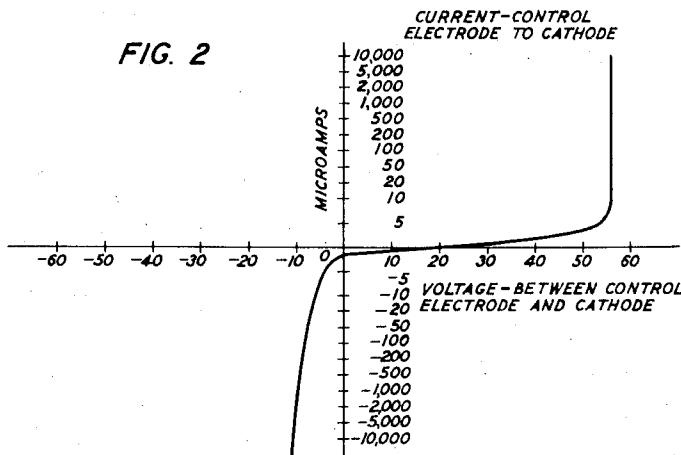
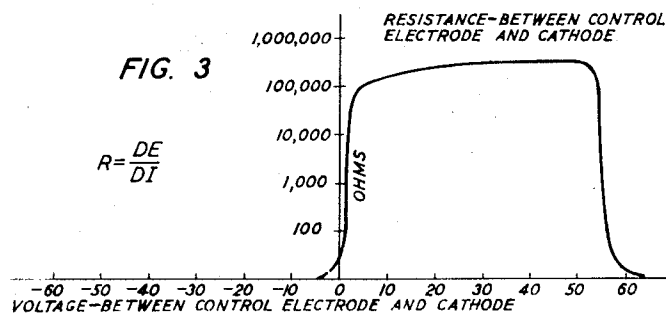


FIG. 3



INVENTOR
W. H. T. HOLDEN

BY
A. G. Friedman
ATTORNEY

UNITED STATES PATENT OFFICE

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PEAK VOLTAGE LIMITER

William H. T. Holden, New York, N. Y., assignor
to Bell Telephone Laboratories, Incorporated,
New York, N. Y., a corporation of New York

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7 Claims. (Cl. 171-119)

The invention relates to peak voltage limiting circuits and more particularly to voltage limiters employing space discharge devices for use in speech transmission circuits.

5 Voltage limiters employing hot cathode gas-filled discharge tubes in shunt to a transmission circuit in which peak voltages are to be limited are well known as for example Patent 1,869,484 to W. A. Knoop issued August 2, 1932. Such
10 arrangements, however, are of the so-called breakdown voltage type and therefore when the critical voltage, at which the limiter is to function, is reached there is an abrupt change in the shunt circuit, from a very high impedance
15 to a relatively low impedance, which has a tendency to cause distortion in the signals being transmitted whose amplitudes are limited.

The present invention is an improvement on limiters heretofore known in that it employs a
20 gas-filled discharge tube of the three-element cold cathode type which functions in a new and novel manner.

In the Journal of the Franklin Institute for September 1922, page 275, et seq., Irving Langmuir, in discussing electric discharges in gases at low pressure states that a discharge between
25 two electrodes, in a gas at low pressure, produces an ionized state in the gas which is described as a "plasma", i. e., a region of intense ionization containing positive ions and negative electrons in about equal numbers and that a variable
30 potential collector placed in the discharge path and given a negative bias will draw positive ions to itself and under typical conditions the ion current will saturate when the collector is given
35 a five to ten volt negative bias. The present invention is based in part on the foregoing discovery but instead of the collector electrode drawing a positive ion current when it is at the
40 cathode potential or slightly negative thereto, it emits electrons, thereby becoming a cathode, if it together with the cathode is coated with electron emitting material, i. e., activated, when
45 it is bombarded with positive ions at voltages of the order of 40 to 50 volts. The same effect will, however, be produced if the collector electrode and cathode are uncoated, but in this case
50 the cathode fall will be several times greater than 40 and 50 volts which is the characteristic of the coated type electrodes. In this case the same operation will take place, but voltages of the order of 150-170 volts will be required.

Under the first condition, i. e., coated electrodes and 40-50 volts ion bombardment, the
55 collector electrode current does not exhibit the

saturation effect described by Langmuir, but rises in value as the collector electrode becomes a cathode and hence the impedance between collector and cathode drop to a very low value.

When the collector electrode is raised in voltage, from a value near that of the cathode, electron current and positive ion current will both
5 flow to it, the former increasing and the latter decreasing slowly as the voltage is raised so that at some potential the total current vanishes and then reverses and rises rapidly, the electrode now
10 becoming a collector of electrons or an anode, the positive ion sheath disappearing and the current increasing about 400 to 1.

Thus it will be seen that in the region where
15 the collecting electrode is sufficiently negative, and if activated, it will function as a cathode and will exhibit a low impedance. In the intermediate range of voltages where it is positive with respect to the cathode yet negative (by approximately the cathode fall of potential) to the
20 plasma it will be surrounded by a positive ion sheath and as the current changes only slowly with voltage the alternating current impedance will be high. Finally, when the electrode becomes
25 a collector of electrons and the positive ion sheath disappears it will become an anode and again exhibit a low impedance. Now, if a discharge is established and maintained between the anode and one cathode of a discharge tube of the type
30 described in U. S. Patent 1,977,254 the impedance looking into the other cathode is subject to wide variations depending upon the voltage applied thereto. Then, at zero voltage between the two
35 cathodes, the one of variable voltage which will hereinafter be called the control electrode, becomes, electrically a part of the other cathode and, therefore, will exhibit an impedance of about
40 the same value as the discharge gap between the anode and first cathode which is of the order of 100 ohms. This impedance, however, rises as the control electrode is made more positive and attains values of from 100,000 to 500,000
45 ohms when the control electrode potential lies between plus 25 and plus 50 volts, these voltages being measured between it and the first cathode. If the control electrode potential is still further increased in a positive direction the impedance ceases to rise and starts to rapidly
50 decrease as the control electrode becomes the anode of a discharge across the gap to the cathode and continues to drop to 100 ohms or less. These figures are based on the use of a discharge tube containing pure argon at 10 milli-

meters of mercury pressure. However, other tubes show similar performance.

An object of the present invention is to limit peak voltages in signal transmission lines without distorting the signals whose amplitudes are limited.

A feature of the invention whereby the foregoing object is attained resides in the employment of a three-element cold cathode gas-filled space discharge device comprising an anode and two other electrodes, which are preferably coated with an electron emitting material, so arranged that a continuous discharge takes place between the anode and one of the other electrodes, a predetermined lower potential is continuously applied to the third electrode and that said other electrodes are connected to opposite sides of the line in which the peak voltages are to be limited.

By this arrangement the normal impedance of the gap between the two electrodes connected across the line is very high but, as before described, when the line voltage rises the impedance of the gap decreases thereby limiting the amplitude of the signal wave.

The invention will be understood from the following description when read in connection with the accompanying drawing:

Fig. 1 showing a high impedance connection between two amplifiers forming a part of the transmission circuit in which it is desired to limit the amplitude of the voltage wave transmitted and having bridged thereacross a voltage limiter comprising a three-element cold cathode discharge device arranged in accordance with the foregoing;

Fig. 2 illustrates the current voltage characteristics of the control electrode of the discharge device when a glow discharge exists between cathode and anode; and

Fig. 3 illustrates the resistance-voltage characteristics under the same conditions.

Referring to Fig. 1 the voltage limiting arrangement 1, of the invention, is connected in bridge of the transmission circuit between the output transformer 2 of the first amplifier 3 and the input transformer 4 of the second amplifier 5.

This limiting arrangement consists of a three-element gas-filled discharge device 6 comprising an anode A, cathode K and a third or so-called control electrode CG, a battery B of the order of 180 volts, resistances R and R₁, and condenser 7.

As previously mentioned the cathode K and the control electrode CG are preferably coated with some well-known electron emitting material. The cathode K is connected to one side of the line, the control electrode CG to the other side of the line through the condenser 7 and the anode A is connected to the cathode K in series with resistance R and the battery B which is so poled that the cathode is negative with respect to the anode. Under this condition there will be a continuous discharge between the anode and cathode.

A further connection also exists, including the high resistance R₁, from the control electrode CG to an intermediate point in the battery B so chosen that the control electrode is positive, by the order of 30 volts, with respect to the cathode and approximately 150 volts negative to the anode.

Fig. 2 illustrates the properties of the control electrode and cathode circuit, K to CG of the device 6. The voltages are those between control electrode and cathode, and the currents those flowing in the lead to the control electrode, when a glow discharge current of from 10 to 15 milliamperes is flowing from anode A to cathode K,

and thence to battery B and through resistance R to anode A. It will be observed that for voltages of the order of 30 volts positive from control electrode to cathode a very small current, of the order of a microampere or less, flows in the control electrode-cathode circuit. Accordingly a linear scale from plus ten to minus ten microamperes has been used, but it is found that when the control electrode potential approaches that of the cathode, or that of the anode, that a rapid increase in current takes place. In order to show this conveniently, the current scale has been made logarithmic beyond the ten microampere point in either direction. This phenomenon will be readily understood when it is noted that the control electrode becomes effectively a part of the cathode at voltages near zero, and that at voltages of about 55 or more it becomes an anode. At intermediate voltages it collects positive ions or electrons from the positive column or plasma of the glow discharge, but these currents are small and change but slowly with voltage.

Hence, the alternating current resistance of the control electrode

$$\frac{dE}{dI}$$

is of a large value in the region from slightly above zero to about 50 volts, but drops to very low values at zero or negative voltages, or at positive voltages in excess of 50, as shown by the curve of Fig. 3.

As long as no potential difference exists between the two sides of the line the impedance between cathode and control electrode, due to the fact that the control electrode is 30 volts positive with respect to the cathode, is of the high order of 200,000 ohms. When voltage is applied to the line and the potential of the control electrode increases in a positive direction, the impedance between the cathode and control electrodes increases until it reaches a maximum of the order of 500,000 ohms at a potential of approximately 50 volts positive on the control electrode, but beyond this critical point the impedance ceases to increase and as the control electrode still further increases its potential in a positive direction, and becomes the anode of a discharge across the gap to the cathode, the impedance rapidly decreases to a very low value of the order of 100 ohms or less.

If on the other hand, the control electrode voltage is lowered below the initial value of +30 volts with respect to the cathode, its impedance will remain substantially constant until it attains a voltage near or equal to that of the cathode. When this occurs, the control electrode will function as a cathode, and the impedance looking into this element will again drop to a low value of the order of 100 ohms.

It will then be apparent that in the circuit arrangement shown, alternating voltages having peak values of 20 volts or less will suffer little or no effect, the only attenuation in passing from transformer 2 to 4 being that due to the presence of a shunt path through the tube, of an impedance of from 100,000 to 500,000 ohms. However, if the alternating voltage amplitudes are increased, for example, to approximately 60 volts, during those portions of the cycle at which the voltage is in excess of 25 volts, there will be a low impedance path through condenser 7, and thence from control electrode CG to cathode K and the other side of the line, and this will be the case on both positive and negative half cycles.

of the alternating voltage. Hence, these peaks will be suppressed or chopped off by the action of the tube 6, as explained.

It is, of course, understood that the specific values mentioned are approximate only and are based on a particular tube construction, battery voltage, etc., and such values are subjected to considerable variation, under varying conditions, without departing from the fundamental theory of operation herein described and claimed.

What is claimed is:

1. In a full wave peak voltage limiter a line in which alternating current potentials transmitted thereover are to be limited, a gas-filled discharge device having an anode and two similar cold electrodes, each of which is adapted to operate as an anode with respect to the other and as a cathode with respect to the anode, said electrodes being connected to opposite sides of the line, direct current means independent of the line for maintaining a constant glow discharge between the anode and one of the electrodes and other direct current means independent of the line for applying a difference of potential between said cold electrodes, the value of which is substantially one-half that required to maintain a discharge therebetween.

2. An arrangement for limiting both positive and negative voltage peaks of alternating current transmitted over a line, said arrangement comprising a three-element gas-filled discharge device having an anode and two similar cold electrodes, said cold electrodes being connected to opposite sides of the line, a multivoltage source of direct current independent of the line and means connecting said source to said anode and cold electrodes in such a manner that a continuous glow discharge will be maintained between the anode and one of said cold electrodes and that a positive potential will be applied to the other cold electrode with respect to the first cold electrode of substantially half the voltage necessary to maintain a glow discharge therebetween.

3. In a peak voltage limiter for alternating current transmission circuits a three-element gas-filled discharge device having an anode and two cold similar electrodes, said two electrodes being connected to opposite sides of the circuit in which the peak voltages are to be limited, a source of direct current connected across said anode and a first one of said cold electrodes for initiating and maintaining a continuous glow discharge therebetween, a second source of direct current connected across said two cold electrodes for maintaining the second cold electrode at a positive potential with respect to the first electrode less than that required to maintain a glow discharge therebetween, the gap between said cold electrodes forming an impedance bridge across said transmission circuit which varies with the line voltage, the value of said second source being so chosen with respect to the sustaining potential of said gap, and to the line voltage peaks to be limited, that for all line potentials below a predetermined critical value the impedance of said gap will be relatively high and when said line potential of either polarity exceeds said critical value, the impedance of said gap will rapidly fall to a relatively low value.

4. In a peak voltage limiter for alternating current transmission circuits, a three-element gas-filled discharge device having an anode and two cold similar electrodes, said two electrodes being connected to opposite sides of the circuit in which the peak voltages are to be limited, a

multivoltage source of direct current and connections therefrom to all three electrodes of the device for initiating and maintaining a continuous glow discharge between the anode and one of said cold electrodes and for maintaining a predetermined positive biasing potential on the other cold electrode with respect to the first cold electrode less than that necessary to maintain a glow discharge between them, and means for isolating said direct current source from the line, the gap between said cold electrodes forming an impedance bridge across said transmission circuit which varies with the line voltage, the value of the direct current potential bridged across said gap being so chosen with respect to the line voltage peaks to be limited and the sustaining voltage of the gap that when, due to the combined effects of said direct current potential and line potential, said cold electrodes are either at substantially zero potential with respect to each other or at a potential difference sufficient to maintain a glow discharge therebetween, the impedance of said gap to line potential will be relatively low.

5. The combination in a voltage limiting system of a transmission line, means for impressing voltages of both polarities and of varying magnitude across the conductors of said line, a gas-filled space-discharge device, an anode and a cathode for said device, a source of potential connected to said anode and cathode and having a voltage sufficient to maintain a constant glow discharge between said anode and cathode, a control electrode forming with said cathode a discharge gap having an impedance which varies with the voltage impressed across said gap, a second source for impressing across said cathode and control electrode a biasing voltage corresponding to a relatively high impedance value for said discharge gap, circuit connections for said cathode and control electrode for including said discharge gap in a circuit across said line to limit the voltage on said line, and circuit means for applying the voltages of one polarity present on said line to said gap in aiding relation to the biasing voltage thereon and for applying the voltages of the opposite polarity in opposing relation to said biasing voltage, the resulting increase or decrease in the voltage across the discharge gap serving in either case to reduce the impedance of said gap to a relatively low value.

6. The combination in a voltage limiting system of a transmission line, means for impressing voltages of alternating polarity and of varying magnitude across the conductors of said line, a gas-filled space-discharge device, an anode and a cathode for said device, a source of direct current potential connected to said anode and cathode and having a voltage sufficient to initiate and maintain a continuous glow discharge between said anode and cathode, a third electrode, a connection between said third electrode and one side of the line, a connection between the other side of the line and said cathode, said third electrode and cathode thereby forming a discharge gap across the line which varies in impedance with the voltage impressed thereacross, a second source of direct current and connections therefor for impressing across said cathode and third electrode a biasing voltage of such value that below a predetermined line voltage of either polarity the impedance of said gap will be relatively high and as the line voltage of either polarity rises above said predetermined value the impedance of said gap will be reduced to a relatively low value.

7. In a peak voltage limiter for alternating current transmission circuits, a three-element cold-cathode gas-filled space discharge device having a cathode and a control electrode connected to opposite sides of the circuit in which the peak voltage is to be limited, a multivoltage source of direct current independent of the line and connections therefrom to all three electrodes of said device for maintaining a continuous glow discharge between the anode and cathode and for maintaining a predetermined positive potential on said control electrode with respect to the cathode substantially one-half that necessary to maintain a discharge therebetween, the gap between said cathode and control electrode forming an impedance bridge across the line which

varies with the line voltage impressed thereacross, the value of said direct current voltage across said gap being so chosen with respect to the breakdown potential thereof, and the line potential to be limited, that when the potential difference across said gap is substantially zero, due to the combined action of said direct current voltage and said line voltage, the impedance of said gap becomes relatively low and when the potential difference across said gap is equal to the voltage required to maintain a discharge thereacross the impedance thereof likewise becomes low, said gap impedance, at all other potential differences between zero and the arc sustaining voltage, being relatively high.

WILLIAM H. T. HOLDEN.